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ICCAT stock assessments of Atlantic billfish

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Abstract. This paper presents a historical overview of the assessments of the Atlantic stocks of blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus platypterus*) that have been conducted by the International Commission for the Conservation of Atlantic Tunas between 1977 and 2000. Details are presented on the data sets used and the models applied, noting the strengths and weaknesses of the assessments. The major causes of uncertainty in the current perception of the status of the stocks are related to some of the data used and to their interpretation, especially historical trends in catch per unit effort. In particular, there are uncertainties about historical catch data, including discards, and about the degree to which longline fishing effort overlaps with billfish habitat. The paper concludes with an account of the efforts that should be made to reduce these uncertainties.

Extra keywords: bycatch, fishery statistics, tuna fisheries.

Introduction

The International Commission for the Conservation of Atlantic Tunas (ICCAT) was established by a 1966 convention with the purpose of facilitating cooperation in research and data collection needed to manage tunas and tuna-like fishes (including billfish) in the Atlantic Ocean and adjacent seas.

This paper presents a historical overview of the ICCAT's assessments of Atlantic blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*) and sailfish (*Istiophorus platypterus*). As every stock assessment can be rather complex, the paper cannot be a thorough historical review without including many details. For this reason, interested readers may wish to consult directly the meeting reports produced in each assessment (available from ICCAT, Corazon de Maria 8, 28002 Madrid, Spain).

The assessment process

The ICCAT Secretariat functions primarily as a coordinating mechanism for the holding of meetings, the collation of data, and the production of reports. Historically, the bulk of the work that leads to assessments has fallen on the government and research institutions of ICCAT contracting parties. (We define 'assessment' as using data and expert information together with a mathematical model of the population, in order to draw conclusions about the status of the stock.) This includes everything from the collection of basic fishery statistics to the collection and analyses of auxiliary information (e.g. hard parts for ageing, tagging, scientific surveys). Until the early 1980s, national scientists who presented the results for discussion at the annual scientific meetings of the Commission often conducted the assessments. Today, a working group that meets specifically for that purpose typically produces ICCAT assessments. During such a meeting, participating scientists review the official statistics and may make changes that are scientifically justifiable; they also bring to the meeting their own analyses, particularly of catch per unit effort (CPUE) data to obtain indices of stock abundance. The Standing Committee on Research Statistics, which makes the final research and management recommendations to the Commission, reviews the results of the working group meetings annually.

In the case of Atlantic billfish stocks, the Enhanced Research Program for Billfish (ERPB) has complemented the assessment approach described above for billfish, a project established by the Commission in 1986 with the purpose of addressing some of the problems affecting the study of billfish population dynamics. These problems, related to uncertainties in overall levels of catch, stock structure, relative abundance and growth, are perhaps not unique to billfish (many bycatch species also have these problems), but have been important enough to hinder billfish assessments for many years. By focusing primarily on basic needs of stock assessment work (catch and effort data, tagging data and

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growth data), the ERPB played a key role in filling obvious gaps. Indeed, part of the work focuses on the collection of statistics from non-contracting parties to the ICCAT that catch billfish (Prince and Brown 1991). It should be noted that non-governmental organizations have played an important role in supporting the ERPB both financially and logistically.

Frequency of assessments

Assessments of Atlantic billfish stocks have been infrequent, partly because of the lack of reliable data as mentioned above. A billfish stock assessment workshop held in Hawaii in 1977 drew attention to key gaps in knowledge and initiated the work on assessments of Atlantic stocks (NMFS 1978).

The ICCAT has conducted four billfish workshops (ICCAT 1981, 1994, 1998, 2001) where assessment data have been put together, revised or updated, primarily for blue and white marlin. However, only during the last two workshops (held in 1996 and 2000) were marlin assessments conducted and used to make management recommendations to the Commission. The remainder of the assessment work conducted historically by the ICCAT has been primarily the work of individual scientists (e.g. Kikawa and Honma 1978; Conser and Beardsley 1979; Farber and Conser 1981; Farber 1982; Conser 1989; Jones and Farber 1996). For an overview of these results see Jones *et al.* (1998).

Sailfish assessment work has been practically nonexistent. The last assessment for sailfish was in 2001, using data up to 1999.

Assessment methods

The efforts made by the ICCAT to put together a historical dataset have focused primarily on landings and fishing effort data. Therefore, all Atlantic billfish assessments have been made with stock production models that only require these basic types of data. Earlier work conducted until the early 1990s involved production models that assumed year-to-year equilibrium conditions (Fox 1975) and used a single series of catch data and a single series of effort data.

This single-series modelling approach used CPUE trends in a single fishery combined with total landings from all fisheries to obtain an overall series of fishing effort. Japanese longline CPUE data were usually chosen for this purpose because they had wide spatial coverage starting in the mid-1950s. Different methods, such as those of Robson (1966) and Honma (1974) were used to standardize CPUE data, taking into account gear and area of operation.

Starting in 1992, the approach to fitting production models developed by Prager (1995) was adopted by many ICCAT scientists and working groups. This approach was deemed preferable to that of Fox (1975) because it did not require the assumption of equilibrium conditions and because it allowed for the use of multiple catch and effort series. In essence, the approach allowed for a more realistic modelling of the fisheries.

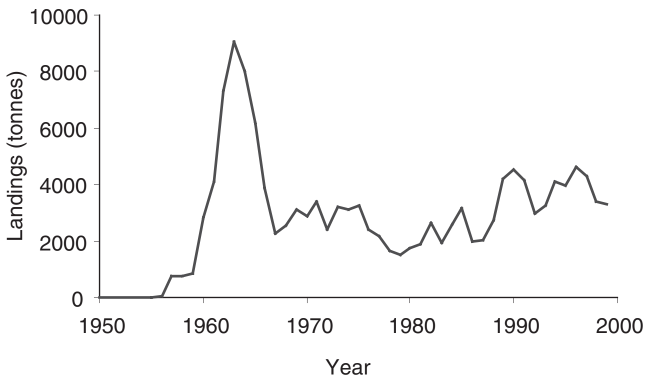

Fig. 1. Estimated landings of Atlantic blue marlin.

Although there has also been progress in the collection of size samples and growth information, the various billfish working groups have decided that these data were insufficient to apply size-based or age-based stock assessment methods, such as those based on virtual population analyses (e.g. Doubleday 1981; Parrack 1986; Gavaris 1988; Powers and Restrepo 1992). To date, ICCAT scientists have not attempted to use the more sophisticated age/size-based assessment tools, such as that of Fournier *et al.* (1998), for billfish, although such methods seem appropriate to more fully utilize the available data.

Current status of Atlantic billfish stocks

The fisheries and current status of billfish stocks are fully described in ICCAT (2001). This section contains a brief overview of the available fishery data and the most recent assessment results.

Blue marlin

The last assessment conducted in 2000, assumed a single Atlantic stock for management purposes. However, previous assessments assumed two stocks separated at 5°N. More than 75% of the landings are incidental to the large offshore longline fisheries that target tuna and swordfish pursued by Brazil, Cuba, Japan, Korea, Chinese Taipei and others. Other major fisheries are the directed recreational fisheries of the USA, Venezuela, Bahamas, Brazil and many states in the Caribbean Sea and off the West coast of Africa. About 60% of the landings are made in the southern hemisphere. Total landings for the Atlantic are shown in Fig. 1. The trend in catches has followed the intensity of the offshore longline fisheries. An interesting feature is the large peak in landings observed for the early 1960s, which was not concurrent with an increase in fishing effort of similar proportions. It is postulated that the increase in catches may have been the result of changes in catchability associated with changes in fishing operations ('learning') early in the history of longlining in the Atlantic Ocean.

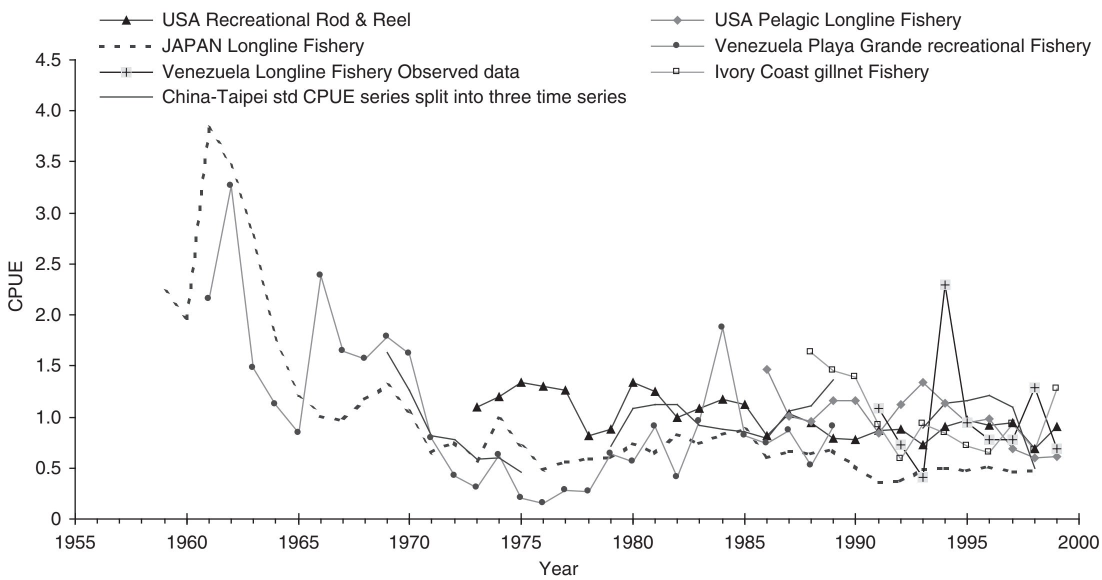

Fig. 2. The catch per unit effort (CPUE) based abundance indices for Atlantic blue marlin from various fisheries. Each series is scaled relative to its own mean.

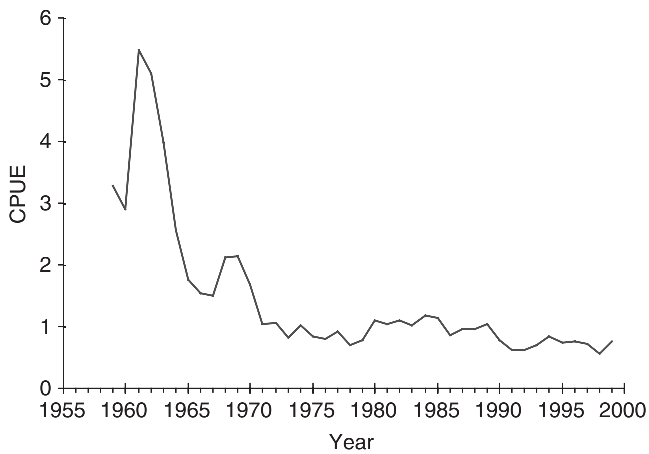

Fig. 3. Overall index of relative abundance for Atlantic blue marlin obtained by combining the series in Fig. 2. CPUE, catch per unit effort.

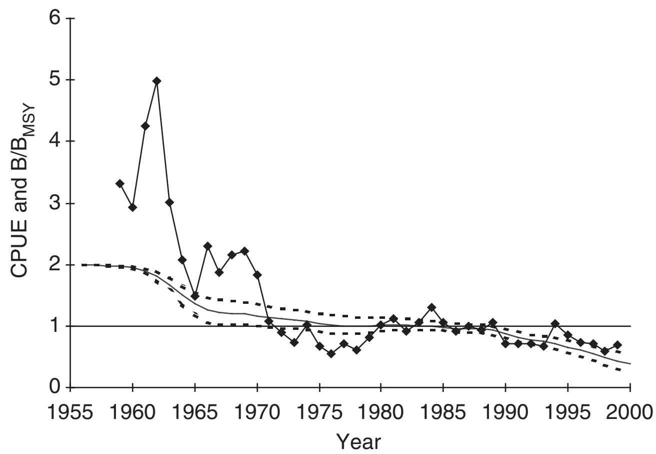

Fig. 4. Composite catch per unit effort (CPUE) series (symbols) used in the blue marlin assessment compared with model-estimated median relative biomass (solid line) from bootstrap results (80% confidence bounds shown by dotted lines).

Table 1. Resources as estimated by the International Commission for the Conservation of Atlantic Tunas

Values are point estimates of quantities that may be highly uncertain

Quantity	Blue marlin	White marlin	Sailfish east	Sailfish west
1999 Yield (t)	3316	908	Unknown	Unknown
MSY (t)	2000	1300	1390	700
B_{2000}/B_{MSY}	0.4	0.15	Unknown	Unknown
F_{1999}/F_{MSY}	4	>7	Unknown	Unknown

MSY, Maximum sustainable yield; B_{2000}/B_{MSY}, ratio of current stock biomass to the equilibrium biomass that would be expected at the MSY level of exploitation; F_{1999}/F_{MSY}, ratio of current fishing mortality to the fishing mortality that would result in MSY.

The CPUE indices from various fisheries are shown in Fig. 2. These were combined into a single index of stock abundance (Fig. 3) during the last assessment (ICCAT 2001). The 'base case' assessment conducted in 2000 used this combined index of abundance and the total catches in a non-equilibrium production model. The results suggest that the stock is overfished given that biomass is estimated to be 40% of that associated with maximum sustainable yield (Table 1; Fig. 4). The assessment also suggests that current levels of harvest are too high and continue to result in overfishing (Table 1; Fig. 5).

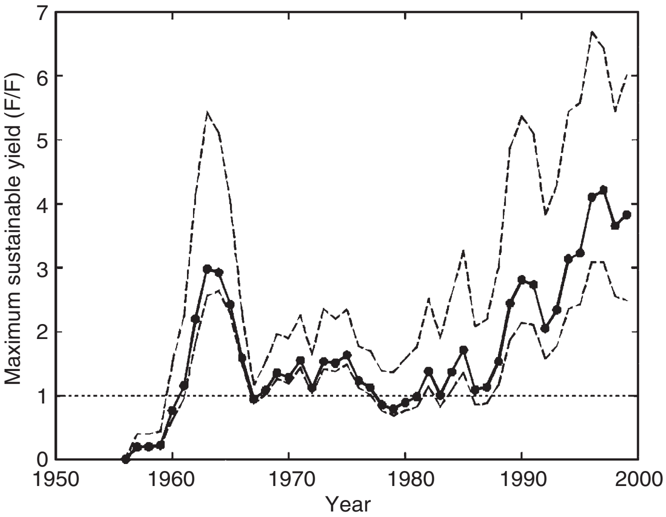

Fig. 5. Estimated median relative fishing mortality trajectory for Atlantic blue marlin (solid line) with approximate 80% confidence range (dashes lines) obtained from bootstrapping.

One of the main difficulties experienced during stock assessments lies in quantifying the uncertainty in the estimates of stock status. The 2000 workshop considered a range of models and blue marlin data sets, including cases in which much of the historical data were disregarded. Thus, the 'base case' results in Table 1 are one set of estimates among many that were obtained during the workshop. In addition, based on a study that demonstrates a severe 'retrospective pattern' in the base case results, it has been suggested that these results are biased (Uozumi 2001). (A retrospective pattern indicates that, as a new years worth of data are added, the model estimates for the most recent years change substantially and in a systematic fashion.) Therefore, there is disagreement within the ICCAT scientific community about the degree of overfishing of the stock.

Whether the blue marlin stock status is worse off or better off than indicated by the 'base case' assessment cannot be answered by conducting more sensitivity analyses. One important source of uncertainty in the assessment has to do with the assumptions made about the overlap between the distribution of longline fishing effort and blue marlin habitat. Hinton and Nakano (1996) proposed a method that assigns weights to fishing effort observations depending on hook depth with respect to blue marlin depth distribution. This method is reasonable from a biological point of view and should in theory be able to account for the large historical shifts in the horizontal and vertical distribution of the longline fishing gear in the Atlantic Ocean. However, questions remain about the actual observations needed to define marlin depth distribution or hook depth distribution. Ultimately, there needs to be a substantial research investment in historical data validation and in biological investigations of the habitat requirements of Atlantic blue marlin that would allow for a better definition of effective fishing effort with methods such as that proposed by Hinton and Nakano (1996).

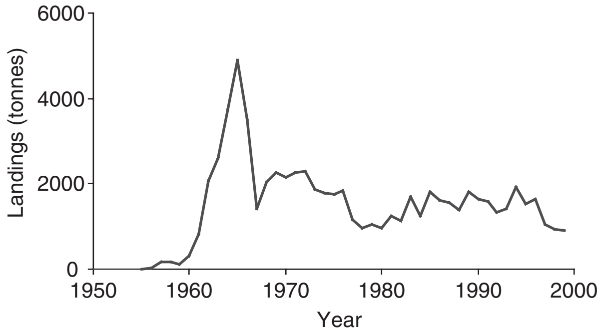

Fig. 6. Estimated total landings of Atlantic white marlin.

White marlin

The 2000 assessment of Atlantic white marlin was also made based on the assumption of a single stock. Estimated total landings are shown in Fig. 6. The spatial distribution of catches is similar to that of blue marlin, with over 60% of the catches being made south of 5°N. Over 90% of the landings are attributed to longline fisheries.

The available CPUE indices from various fisheries are shown in Fig. 7. Compared with blue marlin, the CPUE data for white marlin is more variable (cf. Figs 2 and 7). The 2000 workshop combined these CPUE series into a single index (Fig. 8) that was used in the assessment. The 'base case' assessment of white marlin obtained in 2000 suggests that the stock is greatly overfished (Fig. 9) and that overfishing continues to occur with the current levels of harvest (Table 1; Fig. 10).

The assessment of Atlantic white marlin is characterized by even greater uncertainty than that for Atlantic blue marlin. Several of the model formulations examined during the 2000 workshop resulted in unrealistic estimates and there is some debate about whether the estimated degree of overfishing is accurate or not. However, as explained above for blue marlin, these uncertainties will likely go unresolved until significant resources are devoted to revise the historical data and to better understand the habitat requirements of Atlantic white marlin.

Sailfish (and spearfish)

Most countries reporting fishery statistics to the ICCAT do not distinguish between sailfish and spearfish, so landings data for these two species are usually combined. The assessments have assumed two sailfish stocks, separated at 30°W. Estimated sailfish landings are shown in Fig. 11. The recent major catches of sailfish in both the West and East Atlantic result from artisanal fisheries from many countries in the Caribbean Sea and off West Africa (primarily Ghana, Senegal and Côte d'Ivoire). Directed recreational fisheries for sailfish occur in the West Atlantic from the USA, Venezuela,

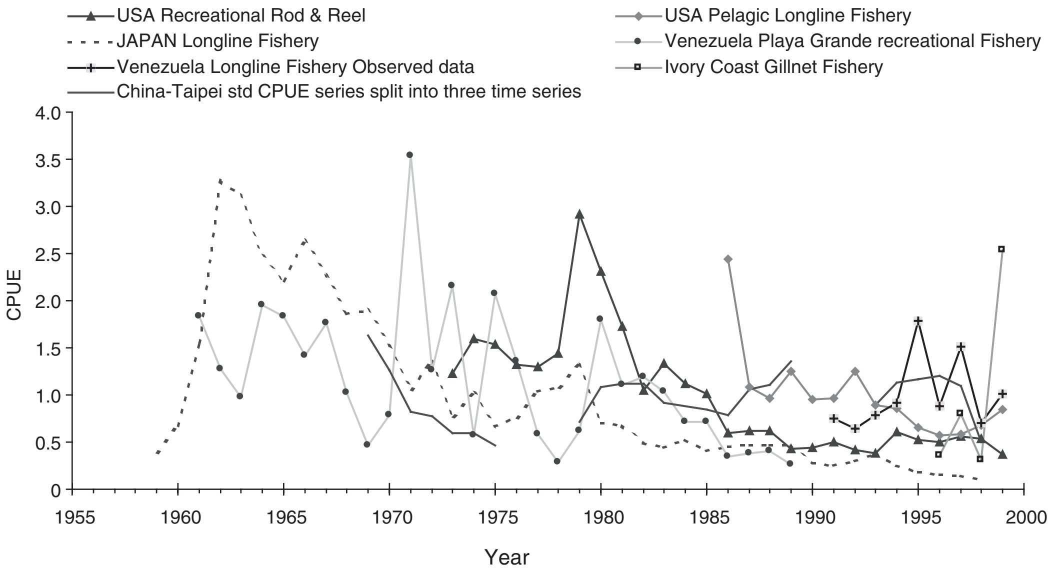

Fig. 7. The catch per unit effort (CPUE) based abundance indices for Atlantic white marlin from various fisheries. Each series is scaled relative to its own mean.

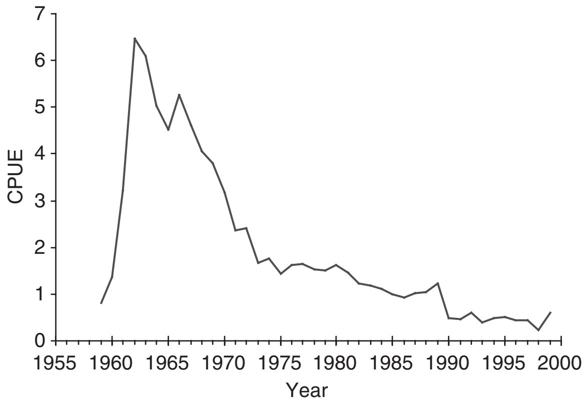

Fig. 8. Overall index of relative abundance for Atlantic white marlin obtained by combining the series in Fig. 7. CPUE, catch per unit effort.

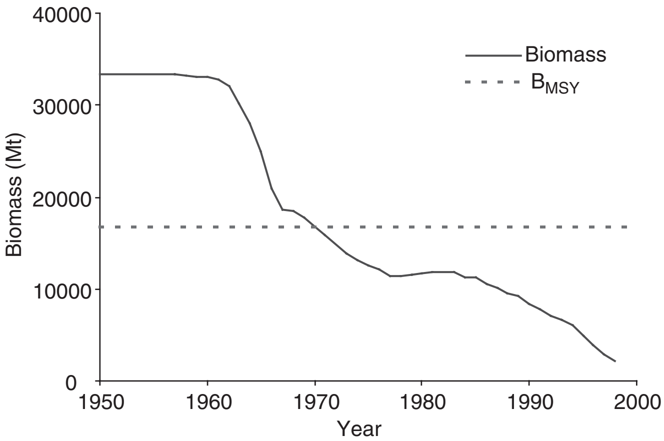

Fig. 9. Biomass trajectory estimated for white marlin using a single combined index of abundance.

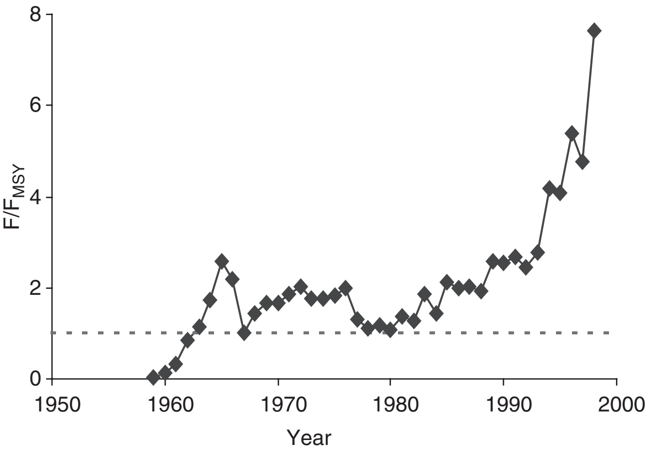

Fig. 10. Relative fishing mortality trajectory for white marlin estimated with a logistic production model applied to catch and a composite catch per unit effort series.

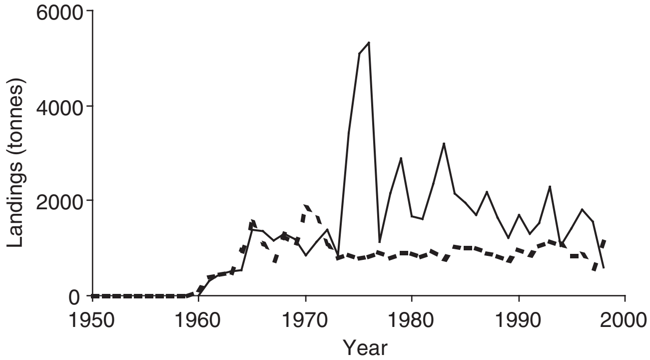

Fig. 11. Estimated landings of East Atlantic and West Atlantic sailfish (solid and dashed lines respectively).

Bahamas, Brazil, Dominican Republic, Mexico and other Caribbean countries. Directed recreational fisheries for sailfish in the East Atlantic also exist off West Africa in Senegal. Prior to the 1970s, the major sailfish/spearfish landings were bycatch from the offshore longline fisheries. The offshore longline fisheries in the West and East Atlantic that land sailfish are by Brazil, Japan, Korea, Cuba, and Chinese Taipei.

The assessment information for sailfish/spearfish referenced in this paper used data up to 1991. After this paper was presented, an updated assessment for sailfish only was conducted in 2001 using data up to 2000, but those results do not alter conclusions drawn. Although important advances were made attempting to split the combined sailfish/spearfish catches, all quantitative assessment models used produced unsatisfactory fits. At present, abundance indices represent the most reliable information and indication of changes in biomass for the stocks of sailfish (sailfish/spearfish). These indices suggest that declines in biomass have taken place, but it is unknown whether biomass levels are below those that would produce maximum sustainable yield.

Discussion and conclusions

The work leading up to the assessments of Atlantic billfish has been difficult and time-consuming. The fact that most billfish landings are a bycatch of tuna longline operations and that the remainder of the landings are largely from recreational or artisanal fisheries, makes it difficult to collect detailed fishery statistics of the type that would be readily available from directed commercial fisheries. The ICCAT has dealt with this through a long-term effort to compile statistics (the ERPB) and by hosting a series of workshops aimed at compiling and revising datasets.

The most recent assessments of Atlantic blue and white marlin are rather basic production models applied to total catch and effort data. These assessments indicate that both stocks are overfished. There are considerable uncertainties about these data, especially relating to historical catches. The commercial fisheries that form the basis for much of the quantitative information used in the assessments are directed mainly at other species. Furthermore, discarding is not generally recorded in the logbooks of many commercial tuna fleets and this practice is therefore a main source of uncertainty. There is also incomplete knowledge about the interactions between marlin behaviour and fishing gears, which makes it difficult to define suitable/marginal habitats for the purpose of fishing effort standardization. It is unlikely that these uncertainties will be resolved by simply holding further data-preparatory workshops without devoting significant resources to validate historical data and to investigate the habitat requirements of marlins. In addition, future assessments might consider using more complex methods that would allow for a more rigorous treatment of uncertainty and use all available data, including size samples. For example, Bayesian methods (Punt and Hilborn 1997) would facilitate the joint examination of alternative hypothesis about the productivity of the stocks. Also, 'integrated' assessment methods such as that of Fournier *et al.* (1998) could allow for the use of available size data and tagging information, and for the weighting of the different sets of information in the assessment model. However, moving in this direction would require additional resources, especially human resources, because such complex models would need to be built and tested outside a workshop setting and over an extended period of time.

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